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subject: Review of Rocket Motor Fires at Umatilla Army Depot

Executive Summary: Representatives from Sandia National Laboratories' Explosive Applications Department performed a brief review of the M55 munitions processing operation at the Umatilla Army Depot. Process areas for further study were suggested to aid in optimizing process robustness. These process areas include: chemical sensitivity, electrical initiation, and mechanical process-induced effects. Based upon information obtained during the site visit, priority should be placed on investigation of mechanical-process related items. Specifically, these include blade wear / pitting / contamination and the placement of the nozzle spray in processing. Additionally, the use of sodium hydroxide solution in place of water should be studied for demilitarization effectiveness and possible process improvement. Although age-induced chemical sensitivity may be a factor this was not assessed in this review.

Background

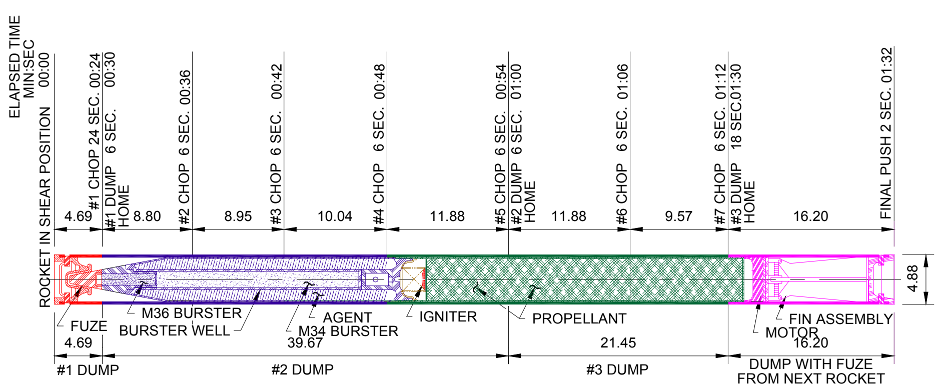
In November of 2004 a fire started in the Rocket Shear Machine (RSM) at Umatilla Ammunition Depot during demilitarization processing of M55 rockets. In April, two additional incidents occurred at that facility during the same process. The Chemical Materials Agency (CMA) asked Sandia National Laboratories (SNL) to provide an independent review for the purpose of identifying aspects of the process and procedures for further investigation. It should be emphasized that Sandia's review and recommendations were not sufficient to identify a root cause of fire initiation.

Venner Saul and Jerry Stofleth of The Explosives Applications Department at SNL visited the Umatilla facility on May 11, 2005 and reviewed physical and photographic evidence and the analysis resulting from the facility's internal investigation process. Several employees were also interviewed about the events (the RSM was not examined). The following summarizes the RSM process as it was presented to SNL personnel. Suggestions were made for further investigation.

Introduction

The M55 is a rocket propelled chemically configured warhead with a diameter of 4.2" and length of 28". The nose contains an impact fuse, followed by a warhead section consisting of a central Comp B or Tetratol burster with an annular fill of about 10 pounds of chemical agent. The warhead section is followed by the propellant section which contains approximately 19 pounds of double base propellant extruded into a single length. The outer perimeter of the cross section conforms to the circular inner radius of the rocket motor body, and the inner void is in the shape of a three-legged cruciform. Behind the propellant section are stabilizing fins.

The demilitarization is performed inside an unmanned room which is monitored remotely and is pseudo autonomous, with manual override during some stages. The munition is initially brought into the facility and loaded on a conveyor system. At the first station, the warhead is punched and drained of chemical contents. The next station shears the munition with a vertical shear blade into 8 sections as follows: the first shear removes the nose/fuse section; the next two shear cuts separate the warhead section into pieces. The fourth shear separates the motor from the last warhead section. The fifth through seventh shear operations separate the propellant into 3 sections. Finally the tail section is pushed out of the shear block. Each fire event reviewed on 5/11 occurred during shear 5, the first propellant cut. See the Rocket Detail below.



Rocket Detail

Propellant initiation issues fall into three categories: 1) Mechanical (process) initiation. 2) Chemical stability. 3) Electrical/igniter. These categories are useful in considering initiation mechanisms.

Electrical: This covers two potential initiation mechanisms. The first involves initiation of the igniter from some energy source which generates current in the igniter leads. The second mechanism consists of direct initiation from an electrostatic discharge applied to the propellant. Without full access to the RSM it is difficult to determine if any part of the process might provide sufficient electrical energy for initiation. However based on discussions with facility personnel regarding the process, sources of electrostatic discharge are apparently minimal. Although it is clear that the fires started during cut 5, (not at the igniter), subsequent initiation of the igniter thru antennae coupling during processing, while a remote possibility, should be considered

Chemical stability: This category largely covers effects which occur prior to munition processing. There is much in available literature about sensitization of the propellant over time via a number of mechanisms, and most are theoretical in nature. One mode involves stabilizer evolving out of the propellant over time, thereby making the propellant more sensitive to external stimulus - these effects might be amplified by the intermittent elevated temperatures during storage. Another mode involves gaseous nitrates which evolve from the propellant to form nitric acid. The nitric acid can cause corrosion and internal leakage of GB into the propellant section. The resulting mixture has been conjectured to gel or crystallize, forming metal azides and picrates as well as gas pressure in the rocket section, hydrogen gas, and other potential unknown effects, many of which result in increased munition sensitivity.

Other considerations involve chemical composition with respect to lot-to-lot variances. It is reasonable to assume that a slight variation in chemical content may affect sensitivity to external stimuli while not affecting thrust performance.

Regardless of the sensitization process, the general mechanism for initiation remains the same. As such, optimizing the process by reducing initiation input amplitudes, particularly localized pressure and thermal inputs, will contribute to reliable processing independent of the propellant status. Further investigation of the munition-shear interaction process would aid in understanding the various pressure and thermal sources which are known to ignite propellant.

Mechanical Processing: This category contains a large number of variables and input stimuli which might result in propellant initiation, and it is here that the bulk of process areas which should be further studied lie.

The shear utilizes a hardened S7 tool steel blade whose design has seen multiple iterations to balance shear performance with system (particularly blade) life. The blade is replaced after approximately 2500 rockets as a matter of course, and is inspected after every 800 rockets. The shear process employs nozzle sprays (water or sodium hydroxide) which both rinse the blade of contaminants and undoubtedly provide some level of cooling and lubrication during the blade shear process. Several methods exist whereby a shear blade could contribute to propellant initiation. Direct methods include high localized pressures which might cause initiation during the shear action, particularly if the blade has some level of wear or damage which would increase the resultant pressures compared with operations using a new blade. Thermal initiation is another possibility resulting from the friction of the blade sliding past the propellant section, and will largely be influenced by the lubricative properties of the water or sodium hydroxide spray, as well as the blade condition. Reaction of sodium hydroxide with metals such as aluminum causes gas production which could further alter the thermal conduction process between the propellant and blade. Indirect process methods include contamination of the blade, particularly during previous cuts through the munition section, which can result in coating the blade with materials possessing increased sensitivity during subsequent processing. Past studies have shown that some single base (NC) propellants exhibit brittle fracture, even at relatively low strain rates. This brittle fracture causes high local pressures which can result in sparking and secondary ignition sources. This general mechanism may well exist in double base propellants, which do contain plasticizer (nitroglycerin and similar compounds) but are highly anisotropic. As such, further investigation of both the propellant's chemical and mechanical properties would be useful.

Pertinent Observations:

- Significant wear and pitting was visible in the one shear blade viewed which was involved in a fire event – this blade had processed less than 1000 rockets before the event, far less than the approximately 2500 rocket lifespan criteria currently used.

  Comments: Seemingly acceptable wear on the shear blade could cause high local pressure levels to be reached in the propellant - without propellant sensitivity data it is difficult to say if the pressures approach the initiation threshold - sensitivity data and subsequent testing would be required to determine this. Additionally, variations in the stability of the propellant due to agent contamination or manufacturing variations might enhance this condition. A contamination of the shear by a variety of materials may provide the impetus for a small, independent reaction to occur as the blade shears into the propellant section, thus initiating the propellant. The blade wear and pitting would increase the propensity of the blade to collect and hold contamination, resulting in contamination-related ignition. The shear blade could pick up burster explosives on cuts 2 or 3 and carry explosives into the propellant. Small pockets of explosive captured in a pitted blade might be pressed into a subcritical mass causing initiation.

- Significant aluminum buildup on the shear blade was visible in photos (cut 4 travels through a thicker section of aluminum). – This observation was verified in communicating with site personnel. Additionally, potential burster contamination on the blade is possible

  Comments: If the aluminum on the blade is drenched in sodium hydroxide just before it shears into the motor section, it can produce free hydrogen which can react to some normally benign stimulus (thermal, pressure, chemical) and cause reaction and propellant fire. As previously mentioned, the resulting gas might in someway alter thermal transfer properties as well.

- The front liquid nozzle has recently been moved to a new location above the blade to prevent potential misalignment during processing (as occurred during a previous incident)

  Comments: The realignment may change the lubricating and cleansing properties of the spray rinse system. Regardless of the initiation mechanism, contamination and potential blade wear issues could be related to the fact that the forward spray nozzle has been relocated to a spot above the blade. Although the actual contribution of the nozzle to successful processing is unclear, the lubrication may contribute to effective cutting by dispersing static charge, cooling, or the spray may simply play a role in washing contaminants off of the blade (particularly burster material) that play a role in initiation. To support this view, the November event resulted in initiation and fire after just a few cuts where the blade was not being sprayed properly. These facts point to a fundamental relationship between blade rinse/spray effectiveness and resulting likelihood of fire – this implies that even deliberate repositioning of the nozzle as has recently occurred may be detrimental to effective, reliable cutting.

- The M62 igniter at the rear of the warhead section contains magnesium – again, if the shear subsequently cuts through the propellant, the propellant could ignite

  Comments: The cut locations are aligned so as not to cut through the igniter, and controls are in place to prevent misalignment. Despite this, Umatilla personnel indicated that some form of manual realignment/override exists; this potential issue should therefore not be discounted.

Summary

Several potential causes for the propellant fires were noted in this review. The root cause of initiation was not identified, however blade wear/contamination (perhaps affected by nozzle position) appears to be a possible mechanism.

Further Considerations

Additional insight into the initiation mechanism might be gained through knowing the quantity of munitions processed between the November and April events, and when the nozzle position change took place relative to the April events. Also reviewing the modifications of the Umatilla RSM versus other systems (particularly with respect to the shear process) may give additional insight into mechanism(s) by which fire occurs – Particular attention should be given to the lubricative and cleaning aspects of the nozzle system.

Propellant and chemical explosive initiation is statistical in nature. As such a successful processing of one munition does not necessarily guarantee successful processing of the next under seemingly identical conditions. The shear blade was apparently designed and optimized for effective cutting/lifespan, and the blade-propellant interface may have not been fully considered. Increased blade inspection frequency and more frequent replacement intervals may also enhance process reliability. The visible damage noted in the blade photos (particularly cratering and scoring) can contribute to initiation through increased localized pressure during shearing and contamination as previously described. Consideration of these issues may help optimize process robustness.

Finally, an analysis of the containment structure response in a worst-case scenario might also be reviewed.